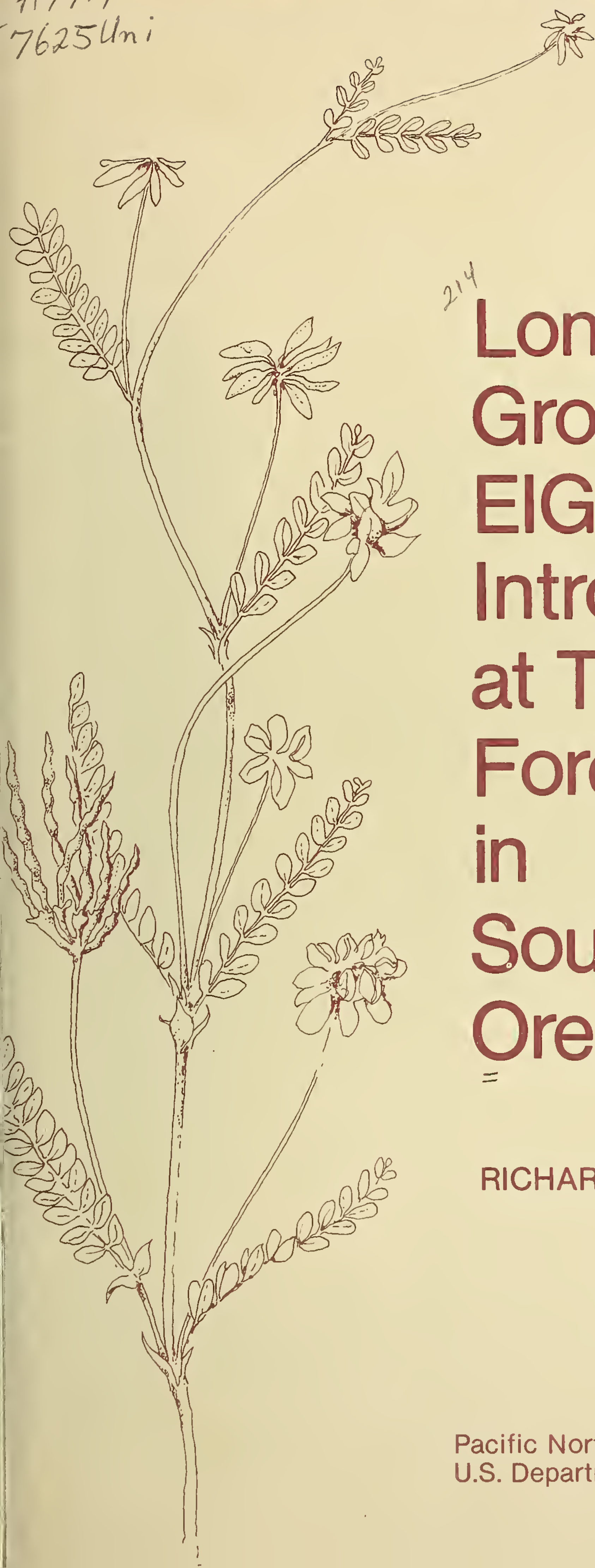

Research Paper PNW-255
May 1979

Long-term Growth of EIGHT LEGUMES Introduced at Three Forest Locations in Southwest Oregon

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ENGLISH EQUIVALENTS

1 meter	=	3.281 feet
1 hectare	=	2.471 acres
1 millimeter	=	0.3937 inch
1 kilogram	=	2.205 pounds
1° C	=	1.8° F

Long-Term Growth of Eight Legumes Introduced at Three Forest Locations in Southwest Oregon

Reference Abstract

Miller, Richard E., and Ray Zalunardo.
1979. Long-term growth of eight legumes introduced at three forest locations in southwest Oregon. USDA For. Serv. Res. Pap. PNW-255, 12 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Using nitrogen-fixing plants in forestry becomes financially more attractive as the costs of fertilizers and their application continue to increase. Eight legume cultivars were screened for suitability in Douglas-fir forests of southwest Oregon. The legumes were sown on concurrently fertilized and unfertilized plots within deer exclosures in three logged and burned clearcuts. Percent cover after the first and during the ninth growing season was clearly greater on 2- by 2-meter plots sown with alfalfa, crownvetch, and birdsfoot deervetch (trefoil) than with wetland deervetch, perennial lupine, annual lupine, flatpea, or hairy vetch. Fertilization influenced 1st-year cover but not subsequent plant cover or height. N fixation was not measured; however, all surviving species were nodulated.

KEYWORDS: Nitrogen fixation, leguminous plants, soil moisture, soil temperature, seeding (erosion control), fertilizer response (soil).

RESEARCH SUMMARY
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Legumes can improve the status of nitrogen and organic matter in soils and thereby can increase growth of associated vegetation. To test the suitability of eight agricultural legumes for forestry uses in the western Cascades of southwest Oregon, we conducted a field trial on three recently burned clearcuts. The legumes were broadcast seeded on concurrently fertilized and unfertilized plots within deer exclosures.

Percent legume cover after the first and during the ninth growing seasons was clearly greater on 2-m x 2-m plots sown with alfalfa, crownvetch, and birdsfoot deervetch (trefoil) than with wetland deervetch, perennial lupine, annual lupine, flatpea, or hairy vetch. Fertilization influenced 1st-year cover, but not subsequent plant cover or height. N-fixation was not measured; however, all surviving species were nodulated. The Douglas-fir near or on the legume plots did not survive the second growing season. Thus, we have no measure of the benefits from these legumes to either the associated vegetation or the soil.

Some of these species could be used in forest management to stabilize soil disturbed by road construction or logging, or to improve growth of associated trees. Characteristics of some species are desirable for both applica-

tions; others are not. For example, ease of initial plant establishment over a wide range of site conditions is a desirable characteristic for stabilizing soil and improving growth of associated trees. Alfalfa, birdsfoot deervetch (trefoil) and particularly crownvetch provided well-stocked stands at all locations when sown with 22.4 kg of seed per hectare. Three of the legumes frequently dominated associated vegetation. This trait is more desirable for soil protection than for silvicultural uses, especially if legumes are admixed with seedlings during plantation establishment. Sowing crownvetch or climbing legumes like flatpea or hairy vetch under pole-size trees, however, may be desirable to insure competitiveness with natural vegetation.

The widespread success of N fertilizers for increasing conifer growth in western Washington and Oregon justifies additional research and development of N-fixing plants as alternative means for supplying N. Some of the legumes tested in this trial on harsh sites may fit this purpose.

CONTENTS

INTRODUCTION

Legumes can improve the status of nitrogen and organic matter in soils and can thereby increase growth of associated vegetation. Using N-fixing plants in agriculture and forestry becomes financially more attractive as the costs of nitrogen fertilizers and their application continue to increase. We conducted a field trial to test the suitability of some agricultural legumes for use in forests of the western Cascade Range of Oregon. We report the 9-year survival and growth of eight legume cultivars sown in three logged and burned clearcuts. We contrast their performance on fertilized and unfertilized plots. We also intended to measure the effects of these legumes on an associated conifer, but seedlings from Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) seeds sown concurrently with the legume seeds failed to survive. Our results show that several of these legumes established vigorous stands in these severe growing conditions.

STUDY AREAS

Location.--Our species trial was located within 0.4-hectare, fenced deer exclosures in three recently clearcut areas in the western Cascade Range east of Roseburg, Oregon (fig. 1). These areas were considered representative of the 600- to 900-m (2,000- to 3,000-ft) elevational zone of the Umpqua River drainage; north, south, and southeast aspects were presented (table 1).

Figure 1.--Location of study areas.

Table 1--Description of the study areas in southwest Oregon

Characteristic	Study areas		
	Calf Creek	Steelhead Creek	Acker Rock
Elevation (meters)	900	760	670
Slope (percent)	10	10	20
Aspect	N.	SE.	S.
Soil texture:			
0-10 cm	loam	clay loam	loam
40-50 cm	clay loam	clay	clay loam
Bulk density[1/] (g/cm^3):			
0-10 cm	0.64	0.79	0.64
40-50 cm	1.18	1.29	1.34
Tentative soil series	Acker	Freezeout	Acker

[1/] Of soil <2 mm in diameter.

Vegetation.--The preceding old-growth, mixed-conifer forests were predominantly Douglas-fir, with some sugar pine (*Pinus lambertiana* Dougl.) and incense-cedar (*Libocedrus decurrens* Torr.). Logging slash from these stands was broadcast burned 5 to 17 months before the legumes were sown in spring 1965. The sparse vegetation that developed after burning was pulled from the plots before the legumes were sown (fig. 2).

Figure 2.--Initial site conditions before sowing at the Steelhead Creek location.

Soils.--Soils of the study areas were deep or moderately deep, well-drained loams or clay loams developed on tuffs and breccias of the extensive Little Butte Volcanic Series (Peck et al. 1964). Clay content and bulk density in these soils gradually increased with soil depth (table 1). The most obvious differences among the soils were in color and structure of the surface soils. At Steelhead Creek, the surface soil consisted largely of hard soil aggregates or "shot;" these were less prevalent at the other locations. Moreover, the dark red-brown soil at Steelhead Creek contrasted sharply with the yellow-brown soils at Calf Creek and Acker Rock. These soil colors were consistent with those of the original pyroclastic parent material.

Climate.--The Mediterranean-type climate of the study areas is characterized by extended periods of drought during the summer. Past annual precipitation averaged 1 524 mm (60 in) at Calf Creek and Steelhead Creek and 1 016 mm at Acker Rock, the most southerly location (Pacific Northwest River Basins Commission Meteorological Committee 1969). Average evaporation stress (Class A Pan) was 1 068 mm and similar for all locations.

METHODS

General

Emergence, survival, spread, and nodulation of each legume were observed on three plots at each location. Two of the three plots were fertilized. Air and soil temperatures, precipitation, and soil moisture content were samples periodically during the first two growing seasons after sowing.

Plant Materials

Seeds of annual or perennial legumes were sown on 2- by 2-m (1 milacre) plots at amounts equal to 22.4 kg/ha for each species. Based on a generally recommended seed density for broadcast sowing of 1,550 live, germinable seeds per square meter (Berglund 1976), our sowing provided excessive seed density for the small-seeded deervetches and sparse density for the remaining, heavier-seeded species (table 2). Each species was randomly assigned to a block of three plots at a given location; the plots were separated by 1.2-m-wide buffer strips. Sowing occurred between March 24 and April 6, 1965; however, the Washington lupine was sown about 1 month later. Although seeds of most species were broadcast without covering to simulate helicopter application, those

Table 2--Plants[1/] sown at the three study areas

Common name	Scientific name	Variety	Seeds per kg	Live no. of pure seeds per m[2/] [3/]
			Thousands	
Alfalfa	*Medicago sativa* L.	OuPuits	496	(939)
Crownvetch	*Coronilla varia* L.	Penngift	297	519
Birdsfoot deervetch (trefoil)	*Lotus corniculatus* L.		1,058	(1,927)
Wetland deervetch (Big trefoil)	*Lotus uliginosus* Schkuhr.	Beaver	2,250	(4,126)
Washington lupine	*Lupinus polyphyllus* L.		40	(72)
Bitter-blue lupine	*Lupinus angustifolius* L.	Spooner	6	13
Flatpea	*Lathyrus sylvestris* L.		22	(44)
Hairyvetch	*Vicia villosa* Roth.		38	(77)

[1/]Scientific and common names are according to Harlan P. Kelsey and William A. Oayton, Standardized plant names. 675 p. J. Horace McFarland Co., Harrisburg, Pa., 1942; other common names are shown in parentheses.

[2/]Seeds donated by Northrup, King, and Company, Albany, Oregon; Grasslyn Company, College Park, Maryland; J. J. Astor Experiment Station, Astoria, Oregon; and Spooner Branch Experiment Station, Spooner, Wisconsin.

[3/]Based on sowing 22.4 kg/ha and known or assumed seed purity and germination percentages. Assumed figures are shown in parentheses.

of both lupines were spot-seeded and covered with 2 cm of soil.

All seeds were inoculated with either an appropriate commercial inoculum or with soil from an established stand of the same species; the seeds were also treated with a commercial molybdenum solution, "Moly-grow," [1/] to promote N fixation.

Fertilization

Fertilizer treatments were systematically assigned to the three plots of each species at each location. The first plot remained unfertilized, the second was fertilized with a complete fertilizer (NPKS), and the third was fertilized with treble superphosphate (PS) to provide an amount of phosphorous equivalent to that in the complete fertilizer. Both fertilizers contained sulfur (table 3).

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

Table 3--Fertilizer treatments applied to each species at the three study areas

Treatment	Fertilizer		Element			
	Type	Rate of application	N	P	K	S
		kg/ha				
None						
NPKS	15-10-10[1/] with microelements	1,120	168	49	92	168
PS	0-45-0	250	0	49	0	25

[1/]This specially formulated fertilizer was donated by the Pacific Supply Cooperative, Portland, Oregon.

Conifer Seeding and Planting

Stratified Douglas-fir seeds were also sown concurrently with the legumes. Nine seedspots, each with three to four seeds, were established within each plot; buffer areas were seeded at the same time and spacing. Because seed germination was extremely poor at Steelhead Creek, two 2+0 Douglas-fir seedlings were planted there in each plot in late spring (1965).

Plant Observations

Legume growth was observed, photographed, and measured at periodic intervals after sowing. The percentage of plot area covered by legumes was ocularly estimated by two observers to the nearest 20 percent in December after the first and second growing seasons. This crude estimate of cover reduced the sensitivity of subsequent statistical analyses; therefore, for the final evaluation made in the middle of the ninth growing season, cover was ocularly estimated to the nearest 5 percent. Then, height of representative plants and maximum distance each species had spread from its plot boundaries was also measured and presence of root nodules was checked on each plot by digging up one of any surviving plants.

Environmental Measurements

Temperature and precipitation at each area were measured at biweekly intervals during the first two growing seasons. Maximum and minimum temperatures were measured with standard mercury and alcohol thermometers at 1-m height; the thermometers were shielded from direct sunlight. Maximum soil surface temperature at two locations per area was recorded by half-buried "Tempils" that melted at specific temperatures over a range of temperatures.

Composite soil samples were collected periodically near the legume plots during the first growing season. Volumetric samples were removed at 10-cm intervals to a depth of 50 cm or more. Two to eight 100-cm^3 samples from each depth class were composited in plastic-lined bags and sealed to prevent moisture loss; moisture content and bulk density were later measured gravimetrically in a subsample dried at 105°C. Soil moisture retention at 3, 8, and 15 bars was determined with a pressure-plate apparatus and at 25 bars by a pressure-membrane apparatus (U.S. Salinity Lab Staff 1954). Gravel, between 2.00- and 6.35-mm diameter, was left in the moisture and moisture-retention samples, because these weathered stone and hard aggregates contained substantial amounts of moisture. Percentages of (1) coarse gravel over 6.35-mm diameter and (2) fine gravel, 2.00- to 6.35-mm diameter were determined by weighing after drying. Particle-size analyses of sand, silt, and clay (2-h settling time) were made by the hydrometer method (Day 1956).

Statistical Analysis

Data were analyzed as a randomized block, split-plot design with species as the whole-plot treatment and fertilizer as the split-plot treatment. Analysis of variance (MANOVA) and orthogonal comparisons were used to identify significant factors and significant differences among means. A probability level of $P<0.05$ was used to judge statistical significance.

RESULTS AND DISCUSSION

First- and Second-Year Emergence and Cover

By the end of the first growing season, the legume species varied greatly in percent cover (table 4). All species had emerged and had established cover at Calf Creek; only two species performed as well at Steelhead Creek or at Acker Rock (table 4).

Table 4--Average foliar cover after the first growing season, by species and study area[1/]

Species	Location		
	Calf Creek	Steelhead Creek	Acker Rock
		Percent	
Alfalfa	60	60	33
Crownvetch	80	27	7
Birdsfoot deervetch	87	73	33
Location average	76	53	24
Wetland deervetch	67	7	0
Washington lupine	13	0	13
Bitter-blue lupine	53	20	0
Flatpea	40	0	0
Hairy vetch	60	13	0
Location average, all species	58	25	11

[1/] Averages the percent cover on two fertilized and one unfertilized plot per species at each location.

The absence of measurable cover for some species in the 1st and especially in subsequent years restricted statistical analysis of performance to that of three species, alfalfa, crownvetch, and birdsfoot deervetch (trefoil); these clearly outperformed the other species (table 4). Averaged over all areas and fertilizer treatments, 1st-year cover did not differ significantly among the three species ($P<0.22$) (table 5); however, birdsfoot deervetch had the greatest average cover (64 percent).

Table 5--Average foliar cover after the first growing season, by species and fertilizer treatment

Species	Fertilizer			Species average
	None	NPKS	PS	
	Percent			
Alfalfa	53	80	20	51
Crownvetch	33	40	40	38
Birdsfoot	73	67	53	64
Fertilizer average	53	62	38	51

Although 1st-year plant cover of these three species varied widely among the three areas, the non-random selection of the areas precluded tests of statistical significance. Average cover was 76 percent at Calf Creek, 53 percent at Steelhead Creek, and 24 percent at Acker Rock (table 4). Average cover on fertilized plots did not significantly differ from that on unfertilized plots; however, the two fertilizers had differing effects ($P<0.05$). Plots treated with NPKS averaged greater cover (62 percent) than those fertilized with PS (38 percent) (table 5). This general trend of more cover following a complete fertilizer did not vary significantly among the three species.

Foliage cover generally increased by the end of the second growing season. Some of this increase was from new germination during the 2d year. Some of these new germinants probably came from hard seeds which are usually impermeable to water; for example, the crownvetch seedlot had 20 percent of hard seed. Cover on the PS-treated plots had improved greatly and was no longer significantly less than that on plots fertilized with NPKS.

Differences in growing conditions probably explained the variable performance of species among the locations. High temperature and moisture stress generally characterized the growing conditions for seed and plants during the first growing season. Although maximum air temperature was similar at the three locations, maximum temperature at the soil surface varied greatly. The microclimate at Calf Creek with its north aspect was probably the most favorable (table 6). Average 1st-year cover was also greatest at this location (table 4). Although the darker colored soil at Steelhead Creek was consistently hottest and presumably more hostile for seed germination and seedling survival, 1st-year cover was better there than at Acker Rock. The greater air temperature on the south aspect at Acker Rock (table 6) suggests that greater evaporational stress may have reduced plant performance at this location.

Table 6--Maximum month air and soil surface temperatures during the first growing season at the three study areas

Month	Air temperature			Soil surface temperature		
	Calf Creek	Steelhead Creek	Acker Rock	Calf Creek	Steelhead Creek	Acker Rock
	°C					
May	29	29	31	52	52	52
June	32	31	34	52	73	66
July	35	36	38	52	73	66
August	38	39	42	59	73	66
September	34	36	36	52	73	59
Average	34	34	36	53	68	62

Moisture stress accompanied these high temperatures. The seeding in March was on soil that was thoroughly moist from previous winter storms. When the perennial lupine seeds were sown in early May, however, soil moisture tension in the 0- to 10-cm layer at Steelhead Creek was already at 10.2 bars (table 7). During May through September in the first growing season, only 64 to 76 mm of rain were measured at the three study areas. All locations showed a general increase in soil moisture tension during the growing season; temporary reductions in tension followed sporadic rainfall.

Table 7--Soil moisture tension during the first growing season, by study area and sampling month[1/]

Date	Location		
	Calf Creek	Steelhead Creek	Acker Rock
		Bars	
April 6	0.2	9.5	0.8
May 13	.6	10.2	2.9
June 2	1.5	16.9	3.4
June16	1.1	5.2	6.8
July 2	9.6	[2/](29.0)	13.5
July 20	(51.9)	(74.2)	--
September 2	10.1	(93.3)	(36.5)

[1/]Soil moisture tensions were determined for the 0- to 10-cm layer.

[2/]Values in parentheses are extrapolated.

Rates of germination and seedling growth generally decrease as the soil dries and hold the remaining moisture with greater force. Germination of garden pea and vetch seeds, however, was not affected by soil water until retention reached 3.8 bars, provided the soil conducted a continuing supply of water to the seed and the seed contacted a sufficient area of the soil (Hadas and Russo 1974a). To ensure an adequate seed-soil contact area, seed diameter should be at least five times the diameter of adjoining soil aggregates (Hadas and Russo 1974b). Large soil aggregates, such as those at Steelhead Creek, retard evaporation from the soil by reducing rate of moisture conductivity, but they slow the rate at which moisture moves to the seed and reduce the seed-soil contact area.

Although germination was probably most disadvantaged at Steelhead Creek, where soil aggregates were especially large, we have no measure of rate and amount of seed germination. Our percentage of plant cover after the first growing season reflects not only germination, but also emergence, survival, and growth. We can reasonably conclude, however, that the three areas represented a wide range of environmental conditions and that the better initial performance of all species at Calf Creek was related to more favorable conditions for germination and growth at that area.

Nine-Year Survival, Growth, and Spread

By the middle of the ninth growing season, seven of the eight species were still present at Calf Creek and only four at Steelhead Creek and Acker Rock (table 8). Foliage cover averaged 79 percent at Calf Creek compared to 42 and 35 percent at Steelhead Creek and Acker Rock. Statistical analysis was again limited to comparing alfalfa, crownvetch, and birdsfoot, the three species with sufficient survival data. In the ninth growing season, differences among these three species were statistically significant ($P<0.05$).

Table 8--Average foliar cover during the ninth growing season, by species and study area

Species	Location		
	Calf Creek	Steelhead Creek	Acker Rock
		Percent	
Alfalfa	97	12	5
Crownvetch	100	97	83
Birdsfoot deervetch	40	18	17
Location average	79	42	35
Wetland deervetch	27	0	0
Washington lupine	7	0	2
Bitter-blue lupine	0	0	0
Flatpea	7	0	0
Hairy vetch	30	23	0
Location average, all species	39	19	13

Average foliage cover on the crownvetch plots had increased from 38 percent after year 1 to 93 percent in year 9; in contrast alfalfa and birdsfoot declined from 51 and 64 percent after year 1 to 38 and 25 percent, respectively, in year 9 (table 9).

Table 9--Average foliar cover at the three study areas during the ninth growing season, by species and fertilizer treatment

Species	Fertilizer			Species average
	None	NPKS	PS	
		Percent		
Alfalfa	45	35	33	38
Crownvetch	97	90	93	93
Birdsfoot	30	23	22	25
Fertilizer average	57	49	49	52

Percent cover was no longer related to fertilizer treatment; the initial benefit from the complete fertilizer over the treble superphosphate was not statistically significant in the 2d and 9th years.

Average height of the 9-year-old legume stands was similar at Calf Creek (39 cm) and Steelhead Creek (42 cm) and nearly twice that at Acker Rock 22 cm). Average height also varied widely among the three species and fertilizer treatments (table 10), yet none of these differences was statistically significant.

Table 10--Average height and maximum distance of spread at three study areas during the ninth growing season, by species and fertilizer treatment

Species	Fertilizer			Average
	None	NPKS	PS	
	Average height (cm)			
Alfalfa	52	48	17	39
Crownvetch	52	37	37	42
Birdsfoot	26	25	35	28
Fertilizer average	43	37	29	36
	Maximum distance spread from plot (cm)			
Alfalfa	0	0	0	0
Crownvetch	260	175	188	208
Birdsfoot	23	88	85	66
Fertilizer average	94	88	91	91

The distance that specific legumes spread from the location of sowing may influence choice of species. Where extensive spreading is desired, crownvetch is a clear choice among the three species that showed consistent survival (table 10). Although distance of spread was similar at the three locations, it was influenced by fertilizer treatment. Crownvetch and birdsfoot reacted significantly differently to fertilization; whereas crownvetch spread farther from unfertilized plots, birdsfoot did not.

Although all surviving species were nodulated, we did not record nodule numbers, size, or color. The Douglas-fir sown or planted near or on the legume plots did not survive the second growing season. Thus, we have no measure of the benefits from these legumes to either the associated vegetation or the soil.

Species Summaries

Additional discussion about individual species follows:

Alfalfa.--This perennial species grew well at all trial locations (fig. 3). It possessed a large, deeply penetrating tap root. Initial vigor of the stands was improved by the complete fertilizer and reduced by treble superphosphate. Especially at Acker Rock, alfalfa growth started much earlier and continued longer in the second growing season on plots treated with the complete fertilizer. Except for limited clipping by rabbits, the foliage was not utilized; therefore, the lack of a continued fertilizer effect through nutrient recycling is puzzling.

Figure 3.--Nine-year-old stand of alfalfa at Calf Creek.

Crownvetch.--Cover of this perennial species increased steadily after the first growing season and averaged 93 percent during the ninth growing season. Moreover, this was the only species to spread from all original plots. Although crownvetch was initially slow to cover the plots at Steelhead Creek and Acker Rock, it attained nearly complete coverage by the 9th year (fig. 4). Fertilizer apparently provided little increase in final stocking or stand height; however, the chlorotic unfertilized stand at Acker Rock contrasted sharply with the dark green of both fertilized plots.

Figure 4.--Nine-year-old stand of crownvetch at Steelhead Creek.

The three varieties of crownvetch adapt to a wide range of site conditions (McKee 1964, McKee and Langille 1967). Crownvetch is frequently used to revegetate cut and fill slopes along highways and mine spoils in the East and Midwest. Although crownvetch can penetrate imperfectly drained, heavy clay soils, it generally is less effective than birdsfoot deervetch (trefoil) on imperfectly or poorly drained soil (Hawk 1964, Waddington 1968). Crownvetch grows well in medium shade of Eastern conifers and deciduous trees; however, it grows best in full sunlight and poorly in full shade.[2] Root growth is affected more by shaded conditions than is top growth (Langille and McKee 1970).

Local experience with crownvetch is limited and generally unsuccessful. Dyrness (1967) sowed inoculated seed of the "Emerald" variety in both fall and spring on a compacted landing at 520-m elevation in the western Cascade Range. Although seed germination was good to excellent, mortality was high during the next growing season and winter; final survival and vigor were poor. The Soil Conservation Service has had little success with crownvetch in the Northwest.[3] Although crownvetch is not listed as a suggested species to control erosion along forest roads in Oregon (Berglund 1976), our observations justify new interest.

Birdsfoot deervetch (trefoil).--The average cover of birdsfoot declined from 65 percent after the first growing season to 25 percent by the ninth growing season; this perennial species spread about 1 m beyond the original plots. Fertilization had no consistent effect on either foliage cover or plant height.

Dyrness (1967) reported good to excellent germination and initial establishment at his test location in the Coast Ranges and at one in the western Cascade Range; however, final stocking was seriously reduced by frost heaving. In contrast, Klock et al. (1975) observed no emergence of fall-sown birdsfoot at

[2] Written correspondence with Fred V. Grau, President, Grasslyn Company, College Park, Maryland, on January 5, 1965.

[3] Personal correspondence with Jack R. Carlson, Plant Material Specialist, Soil Conservation Service, Spokane, Washington, on June 5, 1978.

four locations in the cooler, drier mountain slopes in north central Washington (900- to 2 100-m elevations). Birdsfoot is generally considered a long-lived, winter hardy species adapted to subalpine conditions and annual precipitation between 460 and 1 500 mm (Berglund 1976). Our field trial supports this general observation.

Wetland deervetch (big trefoil).--This perennial deervetch or trefoil performed poorer than birdsfoot in our trial. Survivors were present only at the more mesic Calf Creek location, where cover averaged about 30 percent. Fertilization had no apparent effect.

Dyrness (1967) reported good initial survival and growth but much winter mortality at his location in the Oregon Cascade Range. The better performance reported for his Coast Ranges site and our findings are consistent with general recommendations to use this species where effective precipitation exceeds 1 524 mm (Berglund 1976).

Washington lupine.--Initial and final establishment of this perennial lupine was limited to Calf Creek and Acker Rock; no seedlings emerged at Steelhead Creek, probably because our late sowing was in a dry soil. The 9-year-old plants were robuts (Fig. 5). Although some new plants developed from seed, they were few in number presumably because of seed depredation by birds or rodents. An auxiliary sowing on a highly compacted skid road at Acker Rock produced vigorous and persistent plants. This species has been used in Germany and elsewhere in Europe to improve nitrogen and organic conditions of raw humus soils (Miller 1964).

Bitter-blue lupine.--No live plants of this annual were present after the first growing season. The original seedlings produced second generation plants at Calf Creek and Steelhead Creek, but

Figure 5.--Nine-year-old Washington lupine and ponderosa pine at Calf Creek.

not at Acker Rock. Seed produced by these plants was probably consumed by birds; thus, the complete dependence of this annual on seed propagation lowered its chances to produce a long-lived stand.

Flatpea.--Initial and final establishment of this long-lived perennial was limited to Calf Creek; the few surviving plants appeared healthy but were confined to a single plot. Dyrness (1967) also reported poor germination at both his Cascade and Coast Ranges locations; however, his transplanted seedlings did well. Grunder and Dickson (1948) summarized the use and cultural practices necessary for flatpea in the Pacific Northwest. They stressed its slow early development but ability to compete with native vegetation.

Hairy vetch.--This annual established itself initially at Calf Creek and Steelhead Creek and persisted there. Hairy vetch bested other species at both locations by spreading up to 8 m from the original plots; vigorous plants climbed and dominated associated vegetation. The effects of fertilization were indefinite.

Effects of Fertilization

In some species at some locations, the complete NPKS fertilizer applied at seeding time apparently increased initial cover and plant vigor. Fertilization with nitrogen and phosphorous is generally assumed necessary for successful grass establishment along forest roads of Oregon (Berglund 1976). Unexplainably, however, the effect of superphosphate was to reduce 1st-year foliage cover, especially of alfalfa.

Suitability in Forest Management

Some of these species could be used in forest management to stabilize soils disturbed by road construction or logging or to improve growth of associated trees. Characteristics of some species are desirable for both applications; others are not. For example, ease of initial plant establishment over a wide range of site conditions is desirable for stabilizing soil and improving growth of associated trees. Alfalfa, birdsfoot deervetch, and particularly crownvetch provided well-stocked stands at all locations when sown with 22.4 kg of seed per hectare. This was equivalent to about 939, 1,927, and 519 live pure seeds per square meter respectively, compared to 1,550 per square meter recommended for adequate erosion control along forest roads (Berglund 1976).

Long-lived perennials are generally preferable to annuals whose performance depends on regular production, survival, and germination of seeds. Six of the eight legumes tested were perennial; the exceptions were the two annuals, bitter-blue lupine and hairy vetch. Of the three top performers, crownvetch was particularly well adapted. This perennial legume normally seeds profusely and also spreads with new shoots from widely ramifying lateral roots.[4/] Stems range from 0.6- to 1.8-m long and are strongly branched. Its deeply penetrating root system has numerous lateral roots (McKee 1964).

Three of the legumes frequently dominated associated vegetation. This trait is more desirable for soil protection than for silvicultural uses, especially if legumes are admixed with seedlings during plantation establishment. Sowing crownvetch or climbing legumes like flatpea or hairy vetch under pole-sized trees, however, may be desirable to ensure competitiveness with natural vegetation.

Finally, shade tolerance is another trait that influences species choice. If continued nitrogen fixation is desired, then the ability to grow well in the partial shade of other plants is essential. Crownvetch (McKee 1964, Hawk 1964), flatpea[5/], and Washington lupine have this desired trait.

CONCLUSIONS

1. Alfalfa, birdsfoot deervetch (trefoil), and especially crownvetch formed well-stocked stands during a 9-year period after sowing on recently burned clearcuts in the western Cascade Range of southwest Oregon; survival and foliage cover by five other legumes sown at the same rate of 22.4 kg of seed per hectare was much poorer, especially on harsher sites.

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[4] Personal correspondence with Guy W. McKee, Agronomist, The Pennsylvania State University, University Park, Pennsylvania, on May 22, 1978.

[5] Personal communication with Jack R. Carlson, Plant Materials Specialist, Soil Conservation Service, Spokane, Washington, on November 4, 1977.

2. All surviving species developed nodules on their roots. Although we didn't know if these nodules were functional, their presence and the vigorous top growth suggest that these legumes could improve forest growth by adding N-rich organic matter to the soil.

3. Fertilization with a complete fertilizer or with superphosphate did not affect legume survival or growth after the 1st year.

4. The widespread success of N fertilizers in increasing conifer growth in western Washington and Oregon justifies additional research and development of N-fixing plants as alternative means for supplying nitrogen. Some of the legumes tested in this field trial at three harsh sites may fit this purpose.

LITERATURE CITED

Berglund, Erwin R.
1976. Seeding to control erosion along forest roads. Oreg. State Univ. Ext. Serv. Ext. Circ. 885, 19 p. Corvallis.

Day, Paul R.
1956. Report of the Committee on Physical Analyses, 1954-1955, Soil Science Society of America. Soil Sci. Soc. Am. Proc. 20:167-169.

Dyrness, C. T.
1967. Grass-legume mixtures for roadside soil stabilization. USDA For. Serv. Res. Note PNW-71, 19 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Grunder, Maynard S., and Newell D. Dickson.
1948. Flat pea. Agric. Exp. Stn. Mimeogr. Circ. 104, 8 p. West. Wash. Exp. Stn., Puyallup.

Hadas, A., and D. Russo.
1974a. Water uptake by seeds as affected by water stress, capillary conductivity, and seed-soil water contact. I. Experimental study. Agron. J. 66:643-647.

Hadas, A., and D. Russo.
1974b. Water uptake by seeds as affected by water stress, capillary conductivity, and seed-soil water contact. II. Analysis of experimental data. Agron. J. 66:647-652.

Hawk, Virgil B.
1964. Soil requirements and establishment of crownvetch. Proc. Crownvetch Symp. 1964: 6-8. Penn. State Univ., University Park.

Klock, Glen O., Arthur R. Tiedemann, and William Lopushinsky.
1975. Seeding recommendations for disturbed mountain slopes in north central Washington. USDA For. Serv. Res. Note PNW-244, 8 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Langille, Alan R., and Guy W. McKee.
1970. Early growth of crownvetch under reduced light. Agron. J. 62:552-554.

McKee, Guy W.
1964. Cultivated varieties - origin and description. Proc. Crownvetch Symp. 1964:3-8. Penn. State Univ., University Park.

McKee, Guy W., and Alan R. Langille.
1967. Effect of soil pH, drainage, and fertility on growth, survival and element content of crownvetch, *Coronilla varia* L. Agron. J. 59:533-536.

Miller, Richard E.
1964. Effect of measures to improve humus form on the carbon and nitrogen balance of a soil. Ph.D. dissertation. Univ. Goettingen, Hann Muenden, Germany. (In German). 136 p.

Pacific Northwest River Basins Commission Meteorology Committee.
1969. Climatological handbook, Columbia Basin States, precipitation. Vol. 2, 262 p. + appendices. Vancouver, Wash.

Peck, Dallas L., Allan B. Briggs, Herbert G. Schlicker, Francis G. Wells, and Hollis M. Dole.

1964. Geology of the central and northern parts of the Western Cascade Range in Oregon. Geol. Surv. Prof. Pap. 449, 59 p., illus. Washington, D.C.

United States Salinity Laboratory Staff.
1954. Diagnosis and improvement of saline and alkali soils. Agric. Handb. 60, 160 p. U.S. Dep. Agric., Washington, D.C.

Waddington, D. V.
1968. Effects of soil drainage on the growth of crownvetch. *In* Second crownvetch symposium, p. 44-47. Agron. Mimeogr. Penn. State Univ., University Park.

GPO 988-280

Miller, Richard E., and Ray Zalunardo.
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Using nitrogen-fixing plants in forestry becomes financially more attractive as the costs of fertilizers and their application continue to increase. Eight legume cultivars were screened for suitability in Douglas-fir forests of southwest Oregon. The legumes were sown on concurrently fertilized and unfertilized plots within deer exclosures in three logged and burned clearcuts. Percent cover after the first and during the ninth growing season was clearly greater on 2- by 2-meter plots sown with alfalfa, crownvetch, and birdsfoot deervetch (trefoil) than with wetland deervetch, perennial lupine, annual lupine, flatpea, or hairy vetch. Fertilization influenced 1st-year cover but not subsequent plant cover or height. N fixation was not measured; however, all surviving species were nodulated.

KEYWORDS: Nitrogen fixation, leguminous plants, soil moisture, soil temperature, seeding (erosion control), fertilizer response (soil).

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